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AGRICULTURAL MEMORANDUM NO 614

WIND AND TEMPERATURE IN RELATION TO THE LOSS OF HEAT FROM GLASSHOUSES - F P Sims

INTRODUCTION

The rate at which a glasshouse loses heat increases both with increasing wind and with falling outside air temperature. Extreme values of wind and outside temperature do not in this country occur together, so to calculate the maximum heat loss likely to be experienced it is necessary to know the effect of various other combinations of these 2 factors.

This Memorandum gives the results obtained using computer print-outs of relative wind and temperature frequencies at 3 locations in the West Midlands and one on the South coast.

DATA

The investigation covered the period from November to March inclusive. From data already stored in the computer at Meteorological Office HQ the following stations were selected:

ELMDON (BIRMINGHAM AIRPORT)	1957-1971
PERSHORE (WORCS)	1957-1967
SHAWBURY (SALOP)	1957-1971
THORNEY ISLAND (NR CHICHESTER SUSSEX)	1959-1971

There were a few gaps in the Pershore observations but the remaining stations were complete for the period of years shown above. Hourly observations were used for Thorney Island, but 3-hourly for the 3 West Midland stations. Previous comparisons showed no significant difference in the results obtained by either method for any individual station.

It is interesting to note that in the course of the work over 150,000 observations were analysed by the computer, which perhaps explains why this approach does not appear to have been used before.

RESULTS

Tables 1 to 4 show the computed percentage frequency with which each combination of wind and temperature was observed at the various stations. The tendency for the lowest temperatures to occur with light winds is clearly shown, particularly at the 3 inland stations. In examining the frequencies it is worth noting that 0.1 per cent = 1/1,000, or about 3½ hours in an AVERAGE winter.

CALCULATIONS OF HEAT LOSS

The loss of heat from a glasshouse by transmission through the glass is given by:

$$H = U \times L \quad \ldots . (1)$$

where H = the heat loss in BTU/sq ft/hour
U = the transmission factor ("U-value")
L = the lift in °F (ie the difference between the temperatures inside and outside the glasshouse)

The U-value is known to increase with wind speed. Strictly speaking it only refers to the transmission of heat by conduction through the glass, but in practice is extended to take account of the loss of heat by air leakage from the glasshouse structure, an effect which also increases with the wind speed. Experiments have shown that for a glasshouse in reasonably good condition the loss of heat from this cause amounts to between 10 and 25 per cent of the total heat loss.

Morris (1961) gives the relationship

$$U = 0.75 + 0.05\,W \qquad \ldots\ldots (2)$$

Where W is the wind speed in miles per hour at the standard height of 10 metres. This was deduced from numerous measurements made at NIAE in the late 1950's. Since these measurements were based on amounts of fuel consumed, U in this case refers to the total heat loss. Most of the measurements appear to have been made with wind speeds below 15 miles per hour; linear extrapolation probably gives a slight overestimate of U at the higher wind speeds.

Equations (1) and (2) were used to convert each combination of wind and temperature in Tables 1-4 into a rate of heat loss, using 2 selected levels of inside temperature to calculate the lift. The percentage frequencies then applied to various levels of heat loss and the results shown in Tables 5 and 6 were obtained by addition.

In doing these additions it was noted that none of the very low temperature - light wind occasions appeared in the last 5 columns of either table, and in fact all the higher loss rates occurred with winds over 13 miles per hour and temperatures between 21 and 32°F.

The close agreement between the values for the various locations is significant. All the observations were made on airfields with good open exposures, but in any case winds of appreciable strength would tend to make temperatures fairly uniform over considerable areas.

ESTIMATING HEATING REQUIREMENTS

Tables 5 and 6 show not only the maximum load likely to be imposed on the heating system but also the amount of risk involved in budgetting for economy in boiler design or use of fuel.

Comparisons with established methods are interesting. MAFF Bulletin 115 (1964) recommends using a U-value of 1.4 and this is common practice. It goes on to advise deriving the required lift from the lowest temperature normally to be expected, without however saying how this is arrived at. The absolute minimum temperature likely at the site has long been regarded as giving an overestimate of heating need and the value used has been successively modified over the years to give a more reasonable estimate. See for example Hogg (1966) and Hogg and Davies (1970).

A value of about 20°F has been found by experience to give satisfactory results over the West Midlands. This gives

$$H = 1.4 \times 48 = 67.2 \text{ BTU/sq ft/hour}$$

for an inside temperature of 68°F. From Table 6 we find this covers over 99% of the full heating requirement. This may well be acceptable, and in any case a further 20-30 per cent safety margin is normally incorporated in the design of the heating system. Caution should however be exercised in the case of very exposed sites and a wider margin of safety is desirable.

IMPORTANCE OF SHELTER

The dominance of the wind factor is evident. In conclusion it may be emphasized that considerable savings in capital outlay and fuel consumption can result from making full use of natural or artificial shelter for glasshouses.

REFERENCES

Morris L G (1961) - The heating and ventilation of greenhouses - "Atti del Convegne Internazionale per Laddifesa delle colture e degli allevamenti dalle avversita atmosferische - Torino 22-23 Ottobre 1961"

MAFF Bulletin No 115 (1964) - Commercial Glasshouses

Hogg W H (1966) - Met Office Agricultural Memorandum No 171

Hogg W H and Davies J W (1970) - Met Office Agricultural Memorandum No 347

Any comments or suggestions on this paper should be referred to the author.

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TABLE 1 PERCENTAGE FREQUENCY OF TEMPERATURE AGAINST WIND SPEED
(NOTE: 1 KNOT = 1.15 MILES PER HOUR)

ELMDON 1957-1971. NOVEMBER-MARCH INCLUSIVE

TEMPERATURE °C	°F	WIND SPEED IN KNOTS 0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	≥17
-10	14.0	0.1									
-9	15.8	0.1									
-8	17.6	0.1	0.1								
-7	19.4	0.2	0.1	0.1	0.1	0.1					
-6	21.2	0.3	0.1	0.1	0.1	0.1					
-5	23.0	0.3	0.1	0.1	0.1	0.1	0.1				
-4	24.8	0.4	0.1	0.1	0.2	0.1	0.1	0.1	0.1		
-3	26.6	0.4	0.1	0.2	0.3	0.3	0.2	0.1	0.1		0.1
-2	28.4	0.6	0.3	0.3	0.5	0.4	0.3	0.2	0.1	0.1	0.1
-1	30.2	0.7	0.3	0.3	0.7	0.7	0.4	0.3	0.2	0.2	0.2
0	32.0	0.8	0.3	0.4	1.0	1.1	0.7	0.5	0.3	0.2	0.2
1	33.8	0.7	0.3	0.7	1.4	1.4	1.1	0.7	0.5	0.3	0.3
2	35.6	0.7	0.4	0.6	1.5	1.5	1.2	0.7	0.5	0.3	0.3
3	37.4	0.6	0.4	0.6	1.4	1.4	1.2	1.0	0.6	0.4	0.4
4	39.2	0.6	0.3	0.4	1.5	1.8	1.3	1.1	0.8	0.5	0.7
5	41.0	0.5	0.2	0.5	1.3	1.6	1.5	1.1	0.7	0.4	0.8
≥6	≥42.8	1.0	0.7	1.8	4.8	6.1	6.1	5.7	5.1	3.6	6.5

TABLE 2 PERCENTAGE FREQUENCY OF TEMPERATURE AGAINST WIND SPEED

SHAWBURY 1957-1971 NOVEMBER-MARCH INCLUSIVE

TEMPERATURE °C	°F	WIND SPEED IN KNOTS 0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	≥17
-11	12.2	0.1									
-10	14.0	0.1									
-9	15.8	0.1									
-8	17.6	0.1	0.1								
-7	19.4	0.2	0.1	0.1							
-6	21.2	0.2	0.1	0.1	0.1	0.1					
-5	23.0	0.3	0.1	0.1	0.1	0.1	0.1				
-4	24.8	0.4	0.1	0.2	0.2	0.2	0.1	0.1			
-3	26.6	0.6	0.2	0.2	0.2	0.3	0.2	0.1			
-2	28.4	0.6	0.2	0.2	0.5	0.3	0.2	0.1	0.1	0.1	0.1
-1	30.2	0.8	0.3	0.3	0.7	0.6	0.4	0.3	0.1	0.1	0.1
0	32.0	0.7	0.4	0.5	0.9	0.9	0.7	0.5	0.3	0.2	0.3
1	33.8	0.9	0.7	0.6	1.3	1.3	1.1	0.7	0.4	0.3	0.3
2	35.6	1.0	0.6	0.7	1.4	1.3	1.3	0.8	0.4	0.3	0.3
3	37.4	0.8	0.7	0.7	1.4	1.5	1.2	0.8	0.5	0.4	0.4
4	39.2	0.7	0.5	0.6	1.6	1.6	1.4	0.9	0.5	0.5	0.8
5	41.0	0.6	0.5	0.7	1.1	1.3	1.2	0.9	0.5	0.6	0.7
≥6	≥42.8	1.7	1.5	2.1	5.2	6.4	5.8	5.0	3.5	3.0	7.6

TABLE 3 PERCENTAGE FREQUENCY OF TEMPERATURE AGAINST WIND SPEED

PERSHORE 1957-1967 NOVEMBER-MARCH INCLUSIVE

TEMPERATURE °C	°F	WIND SPEED IN KNOTS 0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	≥17
-12		0.1									
-11	12.2										
-10	14.0										
-9	15.8	0.1									
-8	17.6	0.1									
-7	19.4	0.2		0.1							
-6	21.2	0.3		0.1	0.1	0.1					
-5	23.0	0.5		0.1	0.1	0.1					
-4	24.8	0.5	0.1	0.1	0.2	0.2	0.1				
-3	26.6	0.6	0.1	0.2	0.2	0.1	0.1	0.1	0.1		
-2	28.4	1.0	0.1	0.2	0.4	0.3	0.2	0.1	0.1		0.2
-1	30.2	1.3	0.2	0.3	0.4	0.5	0.5	0.3	0.2	0.2	0.2
0	32.0	1.2	0.3	0.3	0.8	0.6	0.5	0.3	0.2	0.1	0.2
1	33.8	2.5	0.2	0.4	1.1	0.8	0.9	0.7	0.6	0.3	0.4
2	35.6	1.3	0.3	0.5	1.1	1.1	1.0	0.7	0.4	0.3	0.3
3	37.4	1.3	0.3	0.4	1.1	1.3	1.1	0.7	0.4	0.3	0.4
4	39.2	1.0	0.2	0.4	1.2	1.7	1.4	0.9	0.6	0.4	0.6
5	41.0	0.7	0.1	0.4	1.0	1.1	1.4	0.9	0.6	0.4	0.9
≥6	≥42.8	2.1	0.7	1.1	3.9	5.8	6.8	6.2	4.3	4.8	10.2

TABLE 4 PERCENTAGE FREQUENCY OF TEMPERATURE AGAINST WIND SPEED

THORNEY ISLAND 1959-1971 NOVEMBER-MARCH INCLUSIVE

TEMPERATURE °C	°F	WIND SPEED IN KNOTS 0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	≥17
-6	21.2		0.1	0.1							
-5	23.0		0.1	0.1	0.1						
-4	24.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
-3	26.6	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
-2	28.4	0.3	0.4	0.2	0.2	0.3	0.2	0.1	0.1	0.1	0.1
-1	30.2	0.3	0.6	0.4	0.4	0.5	0.4	0.3	0.2	0.1	0.1
0	32.0	0.3	0.8	0.5	0.5	0.6	0.3	0.5	0.2	0.2	0.2
1	33.8	0.4	0.7	0.6	0.8	1.0	0.6	0.5	0.4	0.2	0.2
2	35.6	0.5	1.2	0.8	0.8	1.0	0.7	0.5	0.4	0.3	0.3
3	37.4	0.6	1.3	0.7	1.0	1.0	0.8	0.5	0.4	0.3	0.4
4	39.2	0.4	1.4	0.7	1.0	1.2	0.8	0.6	0.4	0.3	0.4
5	41.0	0.4	1.3	0.7	1.1	1.3	0.9	0.7	0.6	0.5	0.6
≥6	≥42.8	1.8	4.9	3.4	5.0	7.0	6.2	5.9	5.3	5.0	9.3

TABLE 5 PERCENTAGE FREQUENCY AT WHICH RATE OF HEAT LOSS IS WITHIN RANGES SHOWN. MAINTAINED TEMPERATURE INSIDE GLASSHOUSE 15°C (59°F)

	HEAT LOSS PER SQ FT (BTU/HR)							
	<30	30-34	35-39	40-44	45-49	50-54	55-59	60-64
ELMDON	76.7	12.2	6.3	2.8	1.2	0.5	0.2	0.1
PERSHORE	80.7	9.5	5.9	2.6	0.7	0.4	0.1	0.1
SHAWBURY	78.3	11.6	6.0	2.7	1.0	0.3	0.1	
THORNEY IS	84.7	6.6	4.6	2.4	1.0	0.6	0.1	

TABLE 6 AS TABLE 5 BUT MAINTAINED TEMPERATURE INSIDE GLASSHOUSE 20°C (68°F)

	HEAT LOSS PER SQ FT (BTU/HR)							
	<45	45-49	50-54	55-59	60-64	65-69	70-74	75-79
ELMDON	84.6	6.8	4.7	2.3	0.8	0.5	0.2	0.1
PERSHORE	85.9	6.4	4.5	1.8	0.8	0.3	0.2	0.1
SHAWBURY	85.6	6.9	4.2	2.2	0.5	0.4	0.1	0.1
THORNEY IS	88.3	4.9	3.8	1.6	0.6	0.6	0.1	0.1